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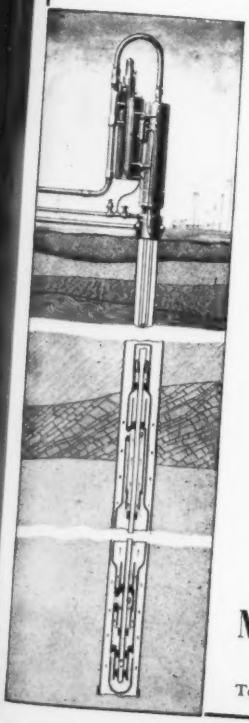

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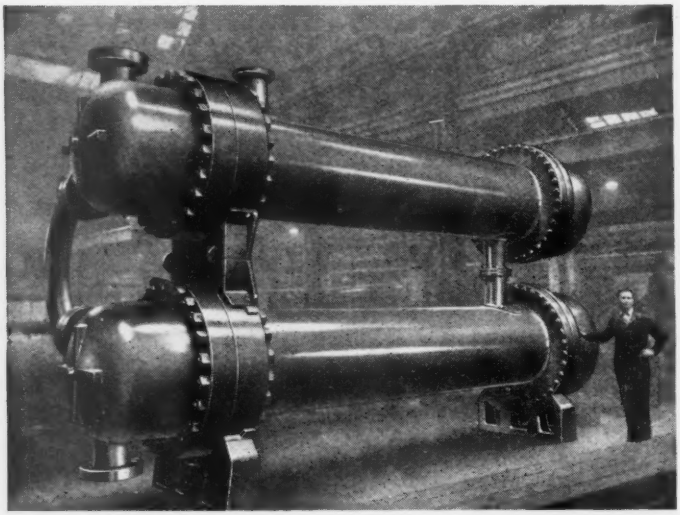

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FUEL OIL DEVELOPMENTS IN THE U.K.

An Address by N. L. HUDSON, M.I.N.A., *and* R. J. BRESSEY, M.A., B.Sc., A.R.I.C., F.Inst.Pet. *to the Oil Industries Club*

THE present Coal to Oil Conversion Campaign started officially with the Minister of Fuel and Power's announcement in Parliament on April 8, 1946, that he was "anxious to expedite a greater use of fuel oil for industrial purposes." Progress was recently reported to the House of Commons in the following terms:

"The conversions that have been effected to mid-March represent an annual consumption of one million tons of oil, equivalent to about 1½ million tons of coal. The additional amount of oil actually used in the coal year 1946–7 will be about 700,000 tons, representing a saving of one million tons of coal. . . . By the middle of 1948, the annual rate of oil consumption represented by schemes of conversion already approved will have been increased to five million tons per annum. The practicability and desirability of going further is under consideration. . . ."

Naturally, one cannot put an extra 5 million tons of oil into use by just waving a wand. In normal times it would represent many years of patient development. Prospective users have got to be sought out and interviewed, their plants surveyed, conversion schemes and layouts prepared and so on. And then more difficult still, the necessary equipment has got to be found—storage tanks, piping, pumps and motors, heaters, filters, burners, and all the hundred-and-one other items

that go to make up a complete installation.

In the main, all this has had to be organized by the oil industry as represented by the Petroleum Board—not to mention the supply of the necessary oil, its transport across the oceans, and its storage and distribution in the U.K. —with all that that implies in the provision of tankage, rail tank cars, road tank wagons, barges, etc.

Fortunately, on the conversion side of the business we have had our wartime experience with the Tar Oils Conversion Campaign to build upon—although that was a small and slow operation compared with the present one. Even so, it is of interest to recall that during the peak year, 1945, nearly 600,000 tons of creosote-pitch mixture were used in substitution for petroleum oil and, during seven crucial years, a total approaching 3,000,000 tons of badly needed tanker space was saved as a direct result of this Campaign. Now tar oils are returning more to their normal uses and petroleum fuel oil is coming into its own again to help meet the country's grave fuel shortage.

No one will be surprised to hear that the materials side of the present conversion campaign is difficult—and is, indeed, the factor which controls the rate of conversion. Steel—particularly plate and sheet for tanks and other equipment—has been the worst trouble and it was recently announced that the coal-oil conversion programme is now bracketed with atomic energy and four other vital sections of industrial activity for top priority in steel supplies. This is, of course, encouraging, but even so, it will inevitably be a little while before the ill-effects of past and present shortages, plus the appalling industrial difficulties of this last tragic winter, are finally overcome.

It may be asked where all this oil is being or will be used, and the answer is in a great variety of industries and processes. Many people, even those associated with the petroleum industry, when thinking of fuel oil, think purely in terms of boiler firing, and the wide variety of its other applications is not realized, That variety is, incidentally, one of the reasons why the fuel oil business is of such absorbing interest to those engaged in it. Unfortunately, it is not possible in the space available to cover the whole field of development, and it is, therefore, necessary to concentrate on a few sections of the trade which are likely to be of the greatest general interest. A brief picture of the present position and the probable trend of future development, will be given, but these forecasts represent the authors' views only.

Central Heating and Steam Raising

It is a little over 20 years since the first completely automatic oil burner was introduced into the U.K. from America, and this was followed by many others—all using the distillate type of fuel, i.e., gas oil/diesel oil.

The most important British contribution in this field has been the development of completely automatic burners able to use a cheaper, non-distillate fuel, i.e. a fuel oil of the 200 seconds type. This development has taken place since 1933, when the fuel oil tax was imposed and is a great feather in the cap of the British oil burner manufacturers.

The size and range of these British Heavy Oil Units, as we call them, has been steadily extended, and they are now employed not only for hot water boilers as normally used for central heating, but also for big steam boilers. At the same time the pre-heaters, controls and safety devices have been improved so that the larger burners can use the heavier grades of non-distillate fuel, such as Pool heavy fuel oil (1000 seconds).

One British firm now manufactures these fully automatic units up to a

rating of 8 million B.Th.U/hr., and it is understood that these large units are being considered for firing a battery of water tube boilers at an important works on the Tyne.

At the present time, as a result of developments during the past 20 or 30 years, the most popular type of plant for oil-firing steam boilers is undoubtedly the pressure jet mechanical atomizing burner fed by means of a combined pumping and heating unit, comprising duplicate pumps and heaters preferably steam operated. The whole plant is usually hand-controlled, but the eventual tendency will probably be to go over to completely automatic units. There is no reason why oil-firing should not share the general trend of industry towards the highest practicable degree of mechanization and automatic control.

In the rebuilt London, one can envisage completely automatic oil burners fitted to large boilers providing the entire heat and domestic hot water requirements of whole blocks of buildings. This idea of block heating may be found to be the best working compromise between the extremes of separate plant for each building and very large scale district heating.

The Palace of Westminster is a good example of the sort of sized block to which this idea could be applied. And, talking of palaces, it has already been announced that Buckingham Palace is going over to oil.

At the other end of the scale, one can visualize development in the direction of small burners suitable for hot water boilers down to a rating of perhaps 40,000 to 50,000 B.Th.U/hour and tests on one such burner are actually in hand. There may also be renewed activity with boiler burner units, development of which was interrupted by the war.

The largest individual boiler proposition at present under discussion, is, of course, the new Bankside Power Station. For amenity reasons it has been decided to use oil as fuel and if the project goes through it will be the first modern power station in the U.K. designed specifically for oil, of which it will require nearly a quarter of a million tons a year. That is, however, 3 or 4 years off yet. It has been stated that by using oil instead of coal it will be possible to reduce the height of the building from 140 to 90 ft and to modify the chimney arrangements.

Steel Making

Big developments are afoot in the steel industry and recently the chairman of the Iron and Steel Board stated that "Conversion to oil burning had already reached a stage when oil consumption was at the rate of about a quarter of a million tons a year, and it was hoped that by the end of 1947 it would be not far short of a rate of one million tons a year."

The bulk of this oil is being used for the manufacture of steel in open-hearth furnaces* previously fired with producer gas, and the steel industry is to be congratulated on the progress which has been made in these conversions, as the first experiments in the U.K. in the oil-firing of open-hearth furnaces were only started two years ago.

Hitherto, the industry had only used oil in the later stages of its operations, such as billet heating and heat treatment, and the conversion of its steel melting furnaces, so long fired with gas, was an almost revolutionary step involving all sorts of problems which were new to the personnel concerned.

This development has, of course, spread from America, where the producer gas-fired open-hearth steel furnace is practically as extinct as the Dodo. It may become so in the U.K. in due course.

In this application, one ton of oil is capable of doing the work of two tons

* Other applications in steel works are soaking pits, re-heating furnaces, mill furnaces, etc.

or so of producer coal, and it is possible to get a considerably greater output (20 per cent perhaps) from the oil-fired furnace. Moreover, there is no producer maintenance nor burning out of gas mains. Results will probably be better still when furnaces specially designed for oil are in use instead of mere conversions.

Although this development is so new on this side of the Atlantic, special burners have already been designed by British firms and are now being manufactured in the U.K. for installation here and for export abroad. These burners are as good as, if not better than, anything which is being used in America.

Railways

The programme now being undertaken by the four main line railways involves the conversion of about 1200 steam locomotives to oil, about 10 to 15 per cent for passenger traffic and the remainder for freight or mixed traffic.

The railways are installing large "oiling depots" at strategic points along the main lines, about 70 being in course of construction. When completed, they will probably store about 50,000 tons of oil for the refuelling of the locomotives. Total consumption may be of the order of 700,000 or 800,000 tons a year.

According to the Minister of Transport, the total cost of conversion, including the cost of storage depots, is estimated at about £1850 per locomotive or a total of nearly £2¼ million.

This conversion of steam locos can be considered as arising out of the coal crisis and in the authors' opinion the economics of the project are doubtful.

The case for the diesel in railway traction is far better, and it is therefore encouraging to know that two of the companies are to try diesel-electric locos for ordinary passenger and freight traffic.

The diesel-electric shunting loco of about 350 b.h.p. has, of course, already established itself in the U.K. There are about 50 in operation and about 200 more under consideration, their oil consumption being 50 tons per year per unit, compared with 600 tons of coal per year for the corresponding steam loco. Small diesel rail coaches driven by a pair of engines totalling a little over 200 b.h.p. are familiar to users of the G.W.R. They are capable of speeds of over 60 m.p.h. and are very useful for branch lines and feeder services.

Now we are to see some full-sized diesel power units comparable with those which have been in operation in the U.S.A. for a number of years. The initial plan is for units of 1650 b.h.p., two of which, coupled together, should be capable of drawing passenger trains at speeds up to 100 miles per hour. Judging from experience in America, there should be scope for the diesel locomotive in the U.K. both for passenger and freight work. Development is, however, likely to be slow and in a few years time the gas turbine may be ready to seriously challenge the diesel.

The gas turbine is attractive because of its fewer working parts—rotating instead of reciprocating—and because of its capacity for producing high powers in a comparatively small and light machine. Reference was made recently to an experimental unit which would make possible a gas turbine electric locomotive less than half the length and two-thirds the weight of the corresponding diesel-electric unit. As regards the relative economics of these two prime movers, it seems that judgement must be suspended until the extent to which the gas turbine can compensate for its lower efficiency, by using a cheaper grade of fuel than the diesel, has been proved under something like service conditions.

Fishing and Marine

Here, the trend towards oil, in the form of diesels or oil-firing, is as marked as

anywhere and it would need a paper on its own to do justice to it. Therefore, apart from just mentioning that coal is now being brought up to London's generating stations and gas works in part by *diesel* colliers, comment will be confined to the fishing industry.

Up to the outbreak of war the main users of oil in this industry were small diesel-engined boats such as the little Seine netters and drifters, with engines up to 150 b.h.p., but development was taking place in connexion with what might be termed the "middle water" trawlers, i.e., boats about 125 feet long fitted with engines of about 450 b.h.p., and this development is continuing. The first oil-fired steam trawler built in the U.K. and fished out of a British port—the *Akita*—also dates from the immediate pre-war period, about 1938.

During the past two years, the diesel has made further great strides. Practically all new small and middle-sized boats are being fitted with diesel engines and one cannot foresee any other motive power for these sizes of craft.

In the case of the bigger trawlers, however, which go out to Iceland, Greenland, and the White Sea—boats up to 175 or 200 feet in length, with engines of 1000 to 1200 b.h.p.—steam still holds its own, with oil-fired boilers, of course. To-day, therefore, many distant water trawlers are being designed and built with oil-fired boilers and many others are being converted from coal. By the end of 1948 there may be as many as 100 of these oil-fired deep-sea trawlers fishing out of the Humber, requiring up to ¼ million tons of oil a year.

Whether the diesel will eventually supersede steam for this type of vessel as well has yet to be seen, but in any case it seems that the future of the fishing industry is with oil.

Agriculture

In agriculture, mechanization and more scientific methods of crop production and treatment are constantly on the increase and driers constitute one important development in this field.

Grass and grain drying plants are being installed on many farms, and also plant for the treatment of those very important raw materials malt and hops!

A grain drier is becoming recognized as the almost essential complement to a combine harvester, as if the grain can be dried a combine can be kept working in almost any weather short of continual rain, and in the English climate that is an enormous boon.

These new driers are in the main oil-fired and in view of the need for an easily handled fuel and close temperature control this is very understandable. Incidentally, about 18 months ago the Ministry of Agriculture and Fisheries announced that from the technical point of view they supported the use of oil as fuel in agricultural driers.

There is undoubtedly a big field for oil in this and other agricultural applications, and oil is rapidly becoming *The Farmer's Fuel*.

Gas Manufacture

The gas industry has long been one of the largest individual users of petroleum oil in the U.K. and since 1939 it has depended on gas oil to an ever-increasing extent to help maintain gas supplies in the difficulties arising from the war and the continuing coal shortage. From about 125,000 tons in 1938 its consumption of gas oil for carburetting water gas had increased to over half-a-million tons by last year and is still rising. As a matter of fact, nearly one quarter of the extra therms of gas available in 1945, as compared with 1938, were derived from gas oil.

These figures relate to the use of gas oil in the conventional type of carburetted water gas plant but, during the last six months, another method of gasifying oil has come into use. It was

developed by the Gas Light and Coke Company and consists essentially of spraying gas oil with steam and air, into horizontal retorts normally used for carbonizing coal. Another gas works has developed the introduction of gas oil into continuous vertical retorts. These new processes must probably be regarded as an emergency method of saving coal by using oil and therefore as unlikely to achieve permanent status.

The use of oil by the gas industry is assisted by means of a Government subsidy. This cost £2¾ million in the 12 months ended October 31, 1946, and is expected to cost an additional £2 million during the current year.

Enough has been said to indicate that fuel oil in the U.K. is enjoying a very lively and interesting present. It is a sad thing that the immediate occasion of this activity is our country's disastrous coal situation and we are as eager as anyone to see this righted at the earliest possible moment. Thereafter, however, we hope fuel oil will enjoy an equally lively future based on its own undoubtedly great merits, and the great services it can render to British Industry in what may then be a highly competitive world.

DEVELOPMENTS IN AUTOMOTIVE LUBRICANTS*

By A. E. HOPE, F.Inst.Pet., M.I.Mech.E., M.S.A.E.†

A QUARTER of a century ago motor lubricating oils were essentially of one general type, namely, blends of conventionally refined petroleum distillates and residual oils with or without the addition of fatty oils or fatty acids. By skilful selection and blending, lubricating oils were prepared which satisfactorily lubricated the automotive engines of those days without giving rise to excessive deposits of carbon and sludge or to excessive wear. However, as engine designs were improved, giving rise to higher efficiencies, it was found that the higher operating temperatures and pressures resulted in a more rapid deterioration of the lubricating oil in service and this, in the main, could be attributed to inadequate oxidation resistance and undue carbonizing tendencies.

To meet this situation a new refining technique was applied to lubricating oils, namely, solvent refining, which hitherto had been almost exclusively reserved for the refining of burning kerosines. It was found that this process materially reduced the carbonizing and sludging tendencies of the oils by removing certain groups of relatively unstable hydrocarbons. The resultant oils, sometimes blended with fatty oils or fatty acids, enabled the petroleum industry to keep in step with developments in the automotive world. This advance, however, was not obtained without some corresponding loss in another direction, namely partial removal of natural oxidation inhibitors. On balance, however, it was generally accepted that the new solvent refined oils were superior lubricants for automotive purposes.

With further improvements in engine design it became apparent that lubricating oils with greater resistance to oxidation and polymerization were necessary to provide efficient lubrication, and the situation was again restored by subjecting the oils to more drastic solvent refining treatments. It was recognized, however, that as the

* Paper read before Northern Branch, Institute of Petroleum, February 18, 1947. † Anglamol, Ltd.

refining treatments increased in severity so the oil was stripped of its natural resistance to oxidation. The ultimate product, medicinal paraffin, had such poor resistence that it could not be satisfactorily employed for engine lubrication. Consequently, from about 1930 the search for chemical products which would delay the rate of oxidation and yet be soluble in petroleum-base mineral oils proceeded with varying success, and before World War II a number of proprietary motor oils on the market contained such materials. Emphasis has been placed upon oxidation and its effective control, as this phenomenon is regarded as the most important item in the deterioration of engine performance. Acidic oxidation products offer a potential source of metallic corrosion, sludge, varnish, and lacquer, whilst soluble polymerization products tend to increase the viscosity of the oil.

Wartime Developments

It is interesting to note that at the outbreak of World War II less than 100 patents had been granted in respect of additives for lubricating oils, and that the impetus to researches caused by the need for victory and survival increased the number to about 300. Many of these materials are unifunctional in character but the most successful additives for the treatment of automotive oils are multifunctional. They are essentially powerful anti-oxidants but they also impart protective properties against the corrosion of the various metals and alloys of the engine, provide extra film strength and oiliness, and in some cases confer detergent and dispersant properties to the petroleum base oil.

Soon after the entry of America into the war it became abundantly clear that some rationalization of supplies of lubricating oils for the road and fighting vehicles of the Allied Armies would be essential. At that time the British and American fighting services had their own specifications covering a multitude of grades of motor engine oils, but urgent discussions resulted in these being reduced to three in number.

In order to cover the requirements of such a vast array of different machines, some powered with gasoline engines and others with diesels, to say nothing of compressors and other auxiliary equipment, with three lubricants, it was obvious that the petroleum base oils would need fortifying with chemical additives. Certain proprietary additives which had already proved their efficacy in civilian service were selected for these purposes and the three oils were blended to meet the requirements of the S.A.E. 10, 30 and 50 specifications under the designations H.D. 10, H.D. 30 and H.D. 50. It is generally accepted that they adequately met the requirements of the fighting services in the various theatres of war, including arctic and torrid zones.

The H.D. oils were required to pass severe acceptance tests laid down by the Ordnance Reviewing Board. Oils submitted for approval had their formulae declared, including the type and quantity of additive, and, apart from the usual physical tests such as viscosity, viscosity index, flashpoint, etc., were subjected in approved mechanical laboratories to the engine tests incorporated in U.S. Specification 2–104. These tests may be summarized thus:

1. A detergency tests made in a single-cylinder Caterpillar diesel engine running at 1000 r.p.m. for 480 hours with oil feed to bearing controlled to 145/150°F and jacket outlet coolant temperature controlled to 175/180°F. Oil performance was evaluated by observing the conditions of the piston, piston rings, and cylinder liner, and estimating liner wear and engine deposits.

2. Examination of the break-in and load characteristics was made in a single-cylinder Caterpillar diesel engine similar to that used in the previous test

but fitted with a special pre-combustion chamber. A new cylinder liner and set of piston rings were used for each test of 3 hours 20 minutes with the engine running at 900 r.p.m., oil feed to bearing controlled at 140°F and jacket outlet coolant temperature controlled to 140°F in the case of S.A.E. 10 oils, and 175°F with S.A.E. 30 grades. At the completion of the test run the piston rings and liner were examined for scratches. This was sometimes referred to as the "Scratch" test.

3. Evaluation of the stability and anti-corrosion properties was made in a 4-cylinder Caterpillar diesel engine running at 1400 r.p.m. for 120 hours with oil feed to bearings controlled at 212°F and jacket outlet coolant temperature at 200°F. A minimum of two new cylinder liners and pistons and two new copper lead bearings were fitted to the engine for each test and the performance of the oil was judged by noting ring sticking, wear, deposits, and bearing corrosion. Also known as the "Hot-Box" test.

4. Estimation of the oxidation and anti-corrosion properties was made in a 6-cylinder Chevrolet gasoline engine running at 3150 r.p.m. for 36 hours with oil feed to the bearings controlled at 265°F for SAE 10 oils and 280°F for SAE 30 and 50 grades and jacket outlet coolant temperature controlled at 200°F. New piston rings and two new copper lead bearings were used in each test and at the end of the run the various engine parts were rated for varnish and sludge deposits using a numerical scale. Bearing corrosion was determined quantitatively by weighing the bearings and the used oil condition was evaluated by chemical and physical analysis. Sometimes referred to as the "2000 miles at 60 m.p.h." test.

5. Oxidation, ring sticking, detergency, and anti-corrosion characteristics were examined in a 3- or 4-cylinder, General Motors 2-stroke diesel engine running at 2,000 r.p.m. for 500 hours. Oil feed to bearings was controlled at 230°F, and jacket outlet coolant temperature at 180°F. Intake air temperature was raised to 105°F. At the end of the test the engine was examined for ring sticking, deposits, wear, and bearing corrosion and the used oil was evaluated by analysis.

It will be appreciated that in this specification emphasis was placed upon the practical performance of the oils in engines and this, undoubtedly, paid a good dividend when the oils were put to practical use. The same tendency was found in the case of aeroplane engine oils for whereas the original British Air Ministry Specification D.T.D. 109 did not contain an engine acceptance clause, but relied upon an empirical laboratory test for the evaluation of oxidation resistance, the latest equivalent specification, D.E.D. 2472, contained an engine test requirement.

The Present

Now that the war is over it is expedient to consider how the advances in the scientific knowledge of engine lubrication resulting from wartime experiences can be applied to more peaceful pursuits.

In America, following discussions between the members of the National Petroleum Association and the American Petroleum Institute, it has been tentatively agreed by the API Division of Marketing Lubrication Committee that the nomenclature of crankcase oils shall be as follows:

> *Regular Type.*—"This term designates motor oil generally suitable for use in internal combustion engines under moderate operating conditions." This is straight mineral oil.
>
> *Premium Type.*—"This term designates motor oil having the oxidation stability and bearing corrosion preventive properties necessary to make it generally suitable for use in internal combustion engines where operating

conditions are more severe than regular duty." This is regular motor oil treated with an anti-oxidant, anti-corrosion additive.

Heavy Duty Type.—"This term designates motor oil having the oxidation stability, bearing corrosion preventive properties, and detergent dispersant characteristics necessary to make it generally suitable for use in both high speed diesel and gasoline engines under heavy duty service conditions." This is a regular motor oil treated with a multifunctional additive with anti-oxidant, anti-corrosion, and detergent properties. It is suggested that the same general scheme of definition could, with advantage, be adopted in Britain.

For many years it has been customary to market motor oils on the basis of specifications and often it has not been appreciated that different oils with the same general specification in terms of viscosity, viscosity index, flash point, pour point, carbon residue, etc., can give very different practical results in engines. Wartime experiences have taught us how to readily evaluate motor oils under practical operating conditions and it is logical to apply these lessons to our marketing schemes. Maintenance engineers and practical motorists are in a receptive frame of mind for a new sales technique based upon performance. Oxidation stability, corrosion inhibition, detergency, ring sticking, and varnish control are terms now more easily understood by the layman than the usual laboratory tests, and a great many ex-service personnel know from their service experiences how well the H.D. oils performed.

Referring to the service properties listed, it might be said that:

Oxidation stability of an oil is its ability to resist the deteriorating effects of use in an engine—effects brought on by exposure of the oil to heat, oxygen of the air, moisture, and agitation, combined with exposure to the surfaces of the various metals with which the oil comes in contact, and to the effects of the products of fuel combustion and of unburnt residues of the fuel such as lead salts or gum.

Corrosion is a property, the presence of which is evident by deterioration and eating away of the surfaces of the alloy bearings such as copper lead or cadmium silver by organic acids. White metal bearings are not affected by oil corrosion but there is an increasing tendency for engine manufacturers to replace babbitt with copper lead in order to boost bearing load capacity when they have increased the power and speed of the engine with no corresponding increase in size.

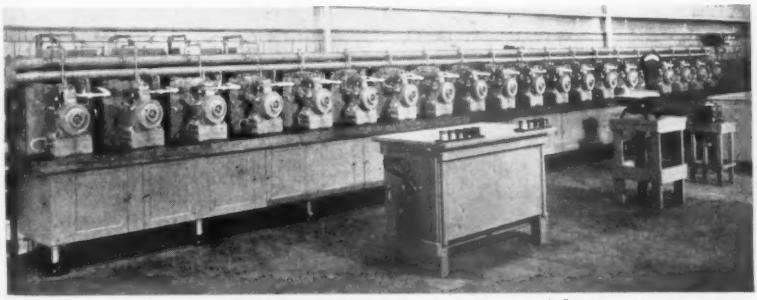

Fig. 1.—A group of single-cylinder, liquid-cooled Lauson engines used for investigation of new additives

Detergency is the property of dispersing or peptizing the insoluble products of oxidation so that they remain in suspension in the oil. They inevitably darken the oil but the efficiency of lubrication and cooling is increased and the engine is kept free from deposits.

Ring sticking is a well understood term and freedom from sticking is assured by controlling oxidation and the formation of piston varnish and lacquer.

Varnish formation results from undue oxidation and can be eliminated by increasing the oil's oxidation stability.

Under peacetime conditions the drastic limitation in the number of grades found necessary by the fighting services is unnecessary and economics may influence the marketing situation. The cost of using additives which convert regular type oils to premium type is usually lower than the heavy duty type treatment, and consequently it may be wasteful to use the latter type in engines not requiring the detergent dispersant properties. This suggests a rational method of providing in Great Britain suitable lubricants for the various types of engines at economic rates, namely, premium type oils for the majority of gasoline and gasoline-paraffin engines and some diesel engines, and heavy duty type oils for these gasoline and diesel engines operating under severe conditions of load or temperature.

The importance of controlling oil oxidation in service has already been stressed and conversely the lack of good oxidation stability shows up in two ways: first, in the form of engine deposits, secondly as bearing corrosion. When deposits of one kind or another collect on the interior of engines to any great extent they seriously affect the operating efficiency of the engine and reduce its service life.

Combustion chamber deposits refer chiefly to carbon and, in a lesser degree, to burned fuel residues. Piston and ring deposits may be varnish on the piston skirt, black lacquer on skirt or ring sides if cylinder wall temperatures have been high, carbon in the ring grooves or on the ring lands and sludge on the scraper rings. Crankcase deposits may be varnish, black lacquer, fuel residues, including carbon and sludge consisting chiefly of thickened oxidized compounds formed from the oil itself. Water, carbon, fuel residues, unburnt or partially burned, are also usually present in sludge in varying proportions. The composition of the sludge depends on the kind of service in which the engine has been run. It depends also on whether the engine is a gasoline or

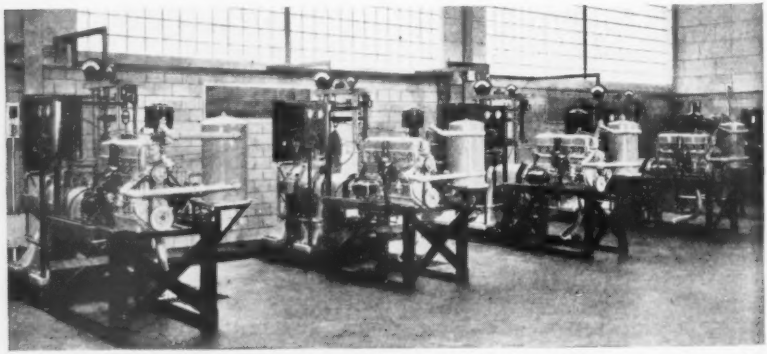

Fig. 2.—Chevrolet passenger-car engines used for testing oxidation and anti-corrosion properties

Fig. 3.—The appearance of a piston after a 36-hour test on a regular type oil

diesel type. It is affected by the design and operating peculiarities of the engine itself; such, for instance, as the provisions made for crankcase ventilation. In the oil passages, may be found any deposits found also in the crankcase.

Bearing corrosion, an engine trouble traceable to oil oxidation can lead to expensive repairs.

The evaluation of engine oil additives is a function of the mechanical research laboratory and Fig. 1 shows a group of single-cylinder, liquid-cooled Lauson engines which have a first-class reputation for preliminary investigational work on new additives. Tests in these engines are conducted under closely controlled conditions. They are fitted with copper lead bearings and when the 120 or 240 hours' tests have been completed the research laboratory begins to get a fair picture of whether the oil being investigated is likely to give good results in full scale engines. If the indications are favourable full scale engine tests are run. Various types of engines are used for this purpose, each being recognized as a means of evaluating some one or more service properties. In the main the engines which proved so valuable for proving the wartime H.D. grades are used.

Fig. 2 is a group of 1942 Chevrolet passenger car engines used for making the 36-hour test already described for evaluating the oxidation stability and corrosion preventive properties of premium type and heavy duty type oils. Procedure has been standardized by the A.S.T.M. and is used by all the recognized research laboratories in America.

After a 36-hour test on a regular type oil a piston skirt would be fairly heavily-coated with varnish (Fig. 3). Other engine parts such as cylinder walls, push rod cover plate, and crankcase, would also have deposits of varnish, and engine bearings and crankshaft would also show varnished surfaces.

Treated with premium or heavy duty type additive the same oil would give a clean piston (Fig. 4). Combination with the additive has given the oil greater resistance to oxidation with the result that no varnish forms. Not only is there no varnish on the various engine parts but also the tendency of the oil to sludging is reduced.

Fig. 4.—A piston after a 36-hour test with an additive-treated oil

It has been stated that corrosion preventive properties are obtained by treating the oil with suitable additives. A new copper lead bearing has a silvery copper sheen, but after a 36-hour test with an untreated oil it would probably be corroded as seen in Fig. 5. The lead

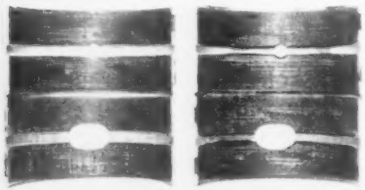

Fig. 5.—A copper-lead bearing corroded after 36 hours with untreated oil

has been eaten away from the bearing surface—dissolved by the organic acids which are products of oil oxidation—leaving the copper mat. This mat, rough as it is, is no longer a good bearing surface.

With another type of regular oil the bearing surfaces are heavily coated with varnish, the result of oil oxidation. When varnish is found on bearings it is certain that there will be varnish deposits on pistons, cylinder walls, and other engine parts. The film of varnish certainly protects the bearing surfaces from corrosion but its sticky nature sets up bad friction effects.

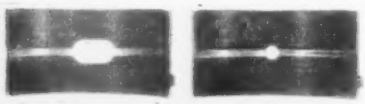

Fig. 6—The additive in the oil has formed a protective coating on the bearing

The smooth bearing seen in Fig. 6 has its surfaces in perfect condition and is as good as new, the additive having imparted a brownish colour to the metal and formed a protective coating which is continually maintained as the engine runs and is impervious to the action of the organic acids. Another type of additive may give a bluish colour to the bearing surfaces and yet be entirely effective in preventing corrosion.

It should not be concluded from these various points that additives are a universal panacea for all engine defects. For instance, for engines in poor mechanical condition, badly worn, leaking, or burning oil, there is no point in using anything better than regular type oil.

Then there is the question of the engine drain period. Because additive treated oils have better resistance to oxidation, etc., some users think they can be used for a longer period. The draining recommendations of the engine makers should be maintained, the advantages being better engine performance, longer engine life, less engine deposits, and lower repair costs.

The Future

Present indications suggest that engine efficiencies have by no means reached a peak and in some quarters B.M.E.P. of 200 and over are visualized. It is problematical whether refined petroleum base oils of the types known at present will possess sufficient oxidation stability for their lubrication, even when fortified with additives of the types now in use. Possibly certain of the new synthetic lubricants which appear to have considerably greater oxidation resistance will provide the base material, but it seems likely that additives will be necessary to make up the deficiency in oiliness, etc., which characterize these new lubricants. The search for better additives goes on relentlessly and experienced observers believe that as engine developments take place suitable additives will be made available to take care of inherent weaknesses in the oils.

These researches require great patience and financial resources. In conclusion, the absolute necessity

of evaluating additives by practical mechanical tests should be stressed. Experience indicates the impossibility of evaluation by chemical and physical laboratory tests, even though such tests may give certain indications during the preliminary stages of development. This explains why the more successful additive manufacturers maintain costly and elaborate mechanical laboratories as well as the far less costly chemical and physical laboratories.

BRITISH OIL EQUIPMENT IN THE CARIBBEAN

THE Council of British Manufacturers of Petroleum Equipment recently issued the General Report of the Mission which, last year, toured the Caribbean area to inquire into the manner in which oil-industry equipment is used under service conditions.

The report makes it clear that, in every country visited by the Mission, British goods are regarded with favour, which is, however, inclined to be prejudiced at present by difficulties in supply and delivery.

In general, no serious complaints about British equipment which is in use were made to the Mission, except that in many cases it is considered too elaborately finished or too heavy for the job compared with the American article, thus giving it a disadvantageous price differential.

Points stressed as being of fundamental importance were that material should be as completely foolproof in design as possible, and of the very best quality to withstand the most stringent field conditions. Other points frequently made to the Mission were that service after purchase could be improved and that British representation in the area and descriptive trade literature could be increased with mutual advantage.

Oil men were very insistent that supplies produced in Great Britain should conform with existing oil industry specifications as outlined in the American specifications ordinarily used.

The report includes some suggestions regarding the packing and shipping of equipment, and concludes with some notes on derricks, drilling equipment, extraction plant, pumps, hand tools, non-ferrous tubes, thermal insulation, welding, and vehicles.

The Mission comprised Messrs E. E. Allen (Mitchell Engineering Co., Ltd.), G. R. Bolsover (United Steel Companies Ltd.), D. H. Carter (Head Wrightson Processes Ltd.), A. G. Ellison (The Yorkshire Copper Works Ltd.), E. T. Forestier (Newman, Hender & Co., Ltd., and others), E. F. E. Howard (Clarke, Chapman & Co., Ltd., and others), F. Kenyon (William Kenyon & Sons Ltd.), H. Martin (Murex Welding Processes Ltd.), F. Pritchard (British Oilfield Equipment Co., Ltd.), and G. H. Thorne (Dawnays Ltd.).

PETROLEUM EQUIPMENT AND APPARATUS

The 1946 edition of the "Oilwell" Machinery and Equipment Catalogue is an attractive and profusely illustrated brochure giving detailed particulars and specifications of drilling production and, other oilfield equipment manufactured and distributed by the Oil Well Supply Company. The catalogue lists equipment and supplies under some 140 headings besides giving details of the more important items.

COUNCIL COMMENTARY

A well attended Council Meeting (twenty-seven strong) was held on May 7, this being the first meeting since the election of officers for the session. The new members were welcomed by the retiring Chairman of the Council—Mr G. H. Coxon.

After the Minutes had been confirmed, Mr H. C. Tett, who had been elected Chairman by ballot, was installed in the Chair, and Mr G. H. Coxon received a well-merited vote of thanks for assiduous and efficient services during his period of office.

The resignation from the Council of Mr C. W. Wood and the appointment of Mr C. Chilvers to the Honorary Secretaryship of the Institute creates two casual vacancies and, in filling these, Council will bear in mind the desirability of maintaining a correct balance of representation between the many-sided interests of the general membership.

Reports were tabled by Awards, By-Laws, Branches, Election, Finance, Public Relations, Publications, and Research Committees and were discussed at varying length.

Points of special interest were in connexion with the Cadman Memorial and the Redwood Medals, further progress towards the issue of a brochure and the adoption of a crest for the Institute, the supply of material for meetings, the *Journal* and the *I.P. Review*, a prospect of the early issue of revised By-laws, and more discussion on proposals in regard to a revived London Branch or Section.

It was reported that a dinner would be held at the Dorchester on June 5 in honour of the Cadman Memorial Lecturer and Council were advised by Awards Committee of their recommendation that the Redwood Medal be awarded to Mr H. S. Gibson, General Fields Manager of the Anglo-Iranian Oil Company, for outstanding work on the production of petroleum. This recommendation was unanimously approved by Council.

A table showing trends of expenditure and foreseeable income presented by the Finance Committee was accompanied by a suggestion from the Chairman of that Committee that very careful consideration should be given to each new proposal involving further expenditure, to make sure that any such items could be fully justified. The action of the Stanlow Branch in refunding £50 to the Parent Institute was warmly approved.

The preparation for publication of a brochure describing the work of the Institute and the design of a crest for the Institute have reached an advanced stage.

Due to still further curtailment of paper supplies very careful thought has to be given to the numbers of each publication which are printed and their most effective distribution, and in this connexion, in discussing the brochure, it was pointed out that whereas it would undoubtedly be of interest to the general membership, it would be of the greatest use to potential members and that adequate distribution among the branches should be ensured.

In the Miscellaneous Items, the Scottish Branch action in encouraging the Glasgow Engineering Centre was endorsed by the General Council and a letter from Mr B. R. Jackson promised a full report in due course on the seventy-fifth anniversary meeting in New York of the A.I.M.M.E., which he had attended officially on our behalf.

ACID SLUDGE DISPOSAL*

By V. BISKE, B.Sc., F.R.I.C., F.Inst.Pet.

THIS short paper is intended only as a brief review of existing methods of sludge disposal and of suggestions for dealing with this problem.

Most industries have, to a smaller or greater extent, the problem of disposing of waste material. The usual sequence of events is that, at first, the unwanted detritus is just dumped in the most convenient place. Then it is found that the place is not, after all, so convenient and other disposal arrangements have to be considered. Attempts are then made to find a use for the material and, in very many cases, the unwanted by-product becomes a valuable economic factor in the operation of the industry.

In the petroleum industry there are several cases of metamorphosis of a material from an incumbrance to a money-making article. Examples that immediately come to mind are the light unwanted front-ends of the kerosine which was the principal product in the latter part of last century and which, for lack of another outlet, were burnt until the development of the spark ignition engine led to the demand for gasoline. Again, in the early days of the Russian petroleum industry, still residues were run to waste until the use of heavy petroleum oils as fuels was developed. More recent examples are the change in outlook regarding both natural and refinery gases, including even hydrogen sulphide among the latter, and, to a lesser extent the various uses that have been found for the extract phase from solvent refining processes, although the promotion of the latter from the ranks of a waste material to that of a valuable member of the product group is not by any means yet complete.

In the case of acid sludges however, by which are to be understood the complex mixtures of sulphuric acid and organic material resulting from the treatment of petroleum oils with sulphuric acid, we are still barely removed from the first stage of development and dumping in the nearest available field, or river, is still an all too common means of disposal.

VARIETIES OF SLUDGE

Within fairly wide limits it can be said that the viscosity of acid sludge increases in line with that of the product being treated, although of course factors such as acid strength, proportion of acid, and treatment temperature have a considerable effect on sludge characteristics.

In the cases of sludges produced from the treatment of such products as gasoline and kerosine, these are extremely fluid and their disposal is not a serious problem. The acid strength is usually higher than in sludges from heavier oils and the sludge can, in many cases, be made to undergo a further stage of degradation by being used to treat fresh material. Dilution of such sludges with water will cause a reasonably easy separation of oil and aqueous phases, and the latter can then be treated for acid concentration or else used as a weak impure acid in certain processes, such as for the neutralization of alkaline refining residues. Acid sludges from light oil refining can sometimes be used for the treatment of lubricating fractions, although difficulties may occur from the lowering of the flash point of the latter by contamination with volatile fractions present in the sludge. Conversely kerosine sludges have been used for gasoline refining.

Another type of product which can be included among the acid sludges obtained from the refining of light oils is the spent acid from catalytic alkylation using a sulphuric acid catalyst.

* Paper read before Stanlow Branch, November 20, 1946.

The acid in this case retains a very large proportion of its original concentration and can either be purified and concentrated for re-use or else, as has been shown by recent work, it can be utilized for the conventional acid refining of lubricating oils.

Apart from distinguishing sludges on the basis of their viscosity they can also be differentiated by classification into sludges resulting from acid treatment and from oleum treatment. The latter are more complex in their composition since the chemical action of the fuming acid causes a greater change in the hydrocarbon fraction which is being treated. Although refining with ordinary sulphuric acid is usually considered as being "chemical" refining, as distinct from "solvent" refining, it is often overlooked that it involves this latter type of action to an appreciable extent and that, apart from removing components from the oil by chemical action, much of the beneficial action of sulphuric acid in petroleum refining can be ascribed to its preferential solubility for certain classes of compounds. Among the latter there may be particularly mentioned oxygen-containing bodies, e.g., naphthenic acids, and compounds which are high in sulphur.

The possibilities of obtaining valuable by-products is much higher in the case of oleum sludges and in fact they are already being used to an appreciable extent for this purpose as a source of sulphonic acids from both kerosine and light lubricating oil refining. The recovery of alcohols and esters from the oleum residues of kerosine refining has also been often proposed, although the increasing use of the Edeleanu process for the refining of fractions intended for illumination does not appear to make such suggestions of much interest for the future.

Since, as a general rule, in the treatment of lubricating fractions oleum is only used for the lighter cuts this results in oleum sludges being of relatively low viscosity and thus more easily manageable. The commoner methods of dealing with such oleum sludges is to mix them with water, to cause separation of the material into an oily and an aqueous layer. The former can then be removed and either blended for use as fuel or, if the oleum treatment has been an appropriate one, used for the production of sulphonic acids, although these latter are often better recovered from the alkaline wash liquor used for neutralizing the acid oil. The aqueous layer can be discharged as effluent, either in the weakly acid condition or else, after neutralization, with any alkaline wastes that may be available. Its concentration is a process whose economics is very doubtful. A certain amount of success has attended the neutralization of acid sludges with ammonia, the resulting ammonium sulphate finding use as a fertilizer.

Having thus briefly enumerated the less objectionable varieties of acid sludge we now come to what has been the refiners bugbear for over half a century, namely the viscous and semi-solid sludges obtained from the sulphuric acid refining of the heavier lubricating oil fractions. The methods proposed for disposing of this material can be divided into two groups, processing it or burning it, although much of the material recovered in the former case is also eventually burnt. Dealing first with the processing of acid sludge this is done with the object of converting it into a more easily disposable form; two principal paths can be followed, either to treat the material from the point of view of recovering therefrom sulphuric acid or else to convert it into a usable substance of the pitch or bituminous type. The processes which have as their object the recovery of sulphuric acid from heavy acid sludge, which usually has an acid content of 25 to 40 per cent, can be divided into two groups. In the one the sludge is digested with water so as to decompose it, yielding a

mixture containing a supernatant oil which can be withdrawn for use as fuel, and a lower layer of diluted acid contaminated with organic matter in solution. This lower layer can be concentrated either by vacuum evaporation or else by the use of hot gases, such as flue gases, to yield an acid of up to about 93 per cent concentration. It is not feasible to carry the concentration any further as the organic substances present tend, at higher acid concentrations, to decompose this latter. The acid produced by this method is dark coloured and has only a limited application, but can be used in certain petroleum refining operations. It has also been suggested to use the acid extracted from the sludge in its more dilute form to produce hydrochloric acid by the addition of common salt, a proposed use for such hydrochloric acid being the activation of bleaching clay. If, prior to digesting with water, the sludge is mixed with highly aromatic light fractions such as are obtained from coal tar, these exert a considerable solvent action and the separation is greatly facilitated.

In certain cases, especially when sludges from light products are being processed, a middle tarry layer is sometimes obtained. This is repeatedly washed with water so as to remove acid and it can then serve as a material for the manufacture of asphalt, being distilled till the residue has attained the desired penetration.

The digestion of acid sludge with water to yield a fuel oil and a weak acid for reconcentration has been the subject of a considerable flow of patents from the middle of the last century onwards. However, whilst numerous processes of this type have been operated, none of them have gained wide acceptance and, in cases where sulphuric acid recovery from the sludge is sought, this is nowadays more often accomplished by heating the sludge direct, thus continuing the decomposition, already initiated in the refining process itself of the sulphuric acid, with resultant formation of sulphur dioxide, by the organic materials. The sulphur dioxide thus obtained is then converted into sulphuric acid by the contact process in a manner analogous to that by which a large proportion of the sulphuric acid of commerce is normally manufactured. The decomposition of the sludge and the production of sulphuric acid from the resultant SO_2 has the dual advantage that it is both more economic and also yields an acid of the normal commercial quality which can be used for any purposes and is not restricted in its application as is the acid resulting from the concentration of the weak acid obtained by water treatment of the acid sludge.

The residual pitch from such heating of acid sludge can be used as a component of asphalt mixtures if a lowering of quality can be tolerated, or else as a solid fuel. The heating has almost completely eliminated the sulphur content so that from this point of view, its use as a fuel is not objectionable. Such residues can conveniently be used as feed for a plant producing pulverized fuel. Old weathered sludges that have attained a solid consistency can also sometimes be burnt by the normal methods used for solid fuels taking however precautions in view of their corrosive character and tendency to soften on heating.

Sludge Burning

The means of disposal which is probably the one most commonly employed, is the burning of the sludge as such. The use of sludge as fuel is not dictated by any desire to obtain a cheap fuel but almost solely as being often the most convenient way of disposing of an unwanted encumbrance, particularly in the case of the smaller refinery. The thicker sludges with which we are at the moment concerned are extremely viscous

and have to be maintained at a fairly high temperature in order to render them pumpable. Sludge burning equipment can be divided into two main groups, that in which the sludge is burnt with the primary purpose of disposing of it, irrespective of whether or not the heat can be usefully employed, and that in which, by the use of equipment similar to that employed for burning the more usual type of fuel, a serious attempt is made to recover some of the calorific value present in the sludge. To the first type belong the rotary kiln type of burner or incinerator in which the heat is either supplied solely by the burning of the sludge itself, in the case of those sludges which are sufficiently fluid to allow of some degree of atomization with an air or steam jet, or with the aid of external heat, supplied for instance by flue gases, for the thicker sludges. The gases from such kilns are passed through waste heat boilers and this is the only way in which any asset is recovered from the burning of the sludge, except of course for the fact that the material itself has been disposed of.

In the case where a more definite attempt is made to utilize the heat content of the sludge this can be accomplished either by fluxing the sludge with a suitable oil and feeding it through a steam or air jet atomizing pattern of burner, sometimes to the usual type of furnace or, frequently, in a "Dutch Oven". In cases where sludge is burnt under boilers in this way it is common practice to utilize two burners, one burning a sludge mixture and the other a conventional fuel oil so that if the sludge burner should momentarily be blocked or extinguished some degree of heating is maintained and provision for relighting made. The burning of completely solid materials originating from acid sludge has already been mentioned. The burning as solid fuel of blends of acid sludge and sawdust is a method which has met with some success.

For burning in atomizing-type burners the sludge has to be kept in a fluid condition, steam agitation being recognized as being better than air for this purpose. The use of aromatic extracts as fluxing oils has, owing to their high solvent power, much to recommend it, although it may seem regrettable that this potentially valuable material should be put to such uses. Even when thus fluxed it is preferable to keep the mixture in constant agitation to prevent settling of the sludge. Cold transfer and storage of sludges is recommended as avoiding many troubles due to coking but is hardly practicable for sludges from heavy lubricating oil. The high sulphur content of sludges results in a highly acidic flue gas, which necessitates maintaining the stack system at above the dew point to avoid corrosion. It is also advisable, if possible, to change over to a conventional fuel some little time before the plant is shut down, otherwise corrosion resulting from the cooling of the equipment is unavoidable.

The atmospheric pollution resulting from the burning of acidic fuels is a factor which has to be borne in mind, the isolated location of many oil refineries being of assistance in this respect. Pollution can also be rendered less evident by the use of high stacks.

Summing up it may be said that the present position is that the chosen means of sludge disposal is, to a considerable extent, governed by the amount of this material that is available. In the case of the small refinery, where the sludge quantity is limited, there seems to be little alternative to either dumping, or else burning after it has been treated to make its combustion reasonably easy. In the case of larger installations there seems to be a good case for recovering the acid content of the sludge, the most effective method being to heat the sludge to drive off sulphur dioxide, the latter being converted to sulphuric acid by a conventional contact plant. The residual coke may well be used as fuel for the sludge heating installation, thus

making the operation to a large extent self-contained.

Suggestions have been made to utilize the sulphur dioxide thus obtained as feed for Edeleanu plants. This is a matter of economics depending upon the amount of make-up SO_2 needed, the degree of purity required being about the same as in sulphur dioxide for contact processing; there is also the cost of compressor plant to deliver sulphur dioxide in the liquid form, although use can probably be made of the compressing equipment in the Edeleanu installation. The direct use of the sulphur dioxide for neutralizing alkaline liquors as in naphthenic acid recovery is another possible outlet, treatment of the resulting sodium sulphite with lime permitting of the caustic soda being regenerated.

The burning of the sludge direct and the utilization for sulphuric acid manufacture of the sulphur dioxide from the resultant combustion gases is hardly practicable owing to the considerable degree of dilution introduced by combustion.

As to what constitutes the boundary of the economic limit between utilizing the sludge as fuel and as a source for sulphuric acid manufacture there exists some divergence of opinion, as costs of acid, transport, labour, etc., come into the picture. It is however fairly certain that the contact manufacture of sulphuric acid is not an economic proposition when the acid recovery is less than 1000 tons per annum, and even this figure which is one quoted by manufacturers of contact plants is probably on the low side. Petroleum refiners do not appear to regard a figure of less than about 5000 tons per annum as worth considering. The possibilities of co-operative action between refineries in close proximity should not be overlooked, two or more installations each having a relatively small amount of sludge might between them make acid recovery worthwhile. The disposal of sludge to plants manufacturing sulphur dioxide and sulphuric acid is another outlet that could be explored.

Acid Sludge Analysis

Finally, whenever attempts are being made to find a use for a product, reliable methods for determining its composition must be available. The analysis of acid sludge is not a matter of great difficulty, provided that certain points are borne in mind. The joint presence of sulphuric and sulphonic acids in sludge necessitates a technique for their separation. It is often assumed that all water-soluble acid can be taken as being sulphuric acid, or alternatively that the latter can be gravimetrically estimated as barium sulphate. Both these courses will lead to errors, since sulphonic acids can be appreciably soluble in water and the barium salts of certain sulphonic acids are insoluble, even in acid solution, and thus come down together with barium sulphate. A method published some years ago (Holzman, E., and Suknarowski, S. *Industr. Engng. Chem. Anal.*, 1935, **7**, 378) consists in neutralizing the sludge with alkali, extracting the oil with benzene, then acidifying and extracting the sulphonic acids with amyl alcohol. The sulphuric acid is determined gravimetrically in the residual aqueous solution. This procedure has given good results in practice.

The estimation of water in acid sludge cannot be satisfactorily carried out by the ordinary Dean and Stark method, due to the decomposition of sulphuric acid by the organic matter present, resulting in the formation of additional water. The Fischer method for water determination can however be applied to acid sludges.

Hopes are sometimes expressed that newer methods of refining will dispense with the use of sulphuric acid and thus eliminate the sludge problem. Despite many changes in petroleum refining methods sulphuric acid, although having lost considerable ground in the refining

of both light and heavy fractions, still remains firmly entrenched and, as no alternative yet appears to be practicable in the case of certain products, particularly such as white oils, it seems that the acid sludge problem must remain for many years to come.

PERSONAL NOTES

John A. Oriel, M.C., M.A., F.Inst.Pet., General Manager of "Shell" Refining and Marketing Co., Ltd., a vice-president of the Institute, and *H. S. Gibson*, B.A., F.Inst.Pet., General Fields Manager, Anglo-Iranian Oil Co., were awarded the C.B.E. in H.M. The King's Birthday Honours List.

R. D. Streeton, A.M.Inst.Pet., has been appointed in control of the newly organized chemical products department of Anglo-American Oil Co., Ltd.

D. A. C. Dewdney, F.Inst.Pet., manager of development department of Esso Development Co., Ltd., has been awarded the U.S. Legion of Merit, degree of of officer, for exceptionally meritorious conduct during the war. From August, 1940 to February, 1941, he was Civilian Oil Adviser to the C.-in-C., Bomber Command, R.A.F. Commissioned in the R.A.F. and posted to the Directorate of Bombing Operations, he studied the economic effects of strategic air attack and was promoted Wing Commander in May, 1944.

Sir Robert Robinson, M.A., D.Sc., LL.D., F.R.S., Waynflete Professor of Chemistry in the University of Oxford and President of the Royal Society, has been awarded the Albert Medal of the Royal Society of Arts for "his outstanding contributions to the advancement of organic chemistry." This medal is the highest award of the Society and was struck in 1864.

STUDENTS' SECTION (LONDON BRANCH)

Over twenty members of the Section paid a visit to The Ford Motor Company's Works at Dagenham, Essex in the afternoon of April 16, 1947.

The visit was particularly successful and brought out forcefully the efficiency of modern manufacturing methods and the degree of control exercised in ensuring uniformity under conditions of mass production.

The last meeting of the Section, which took the form of a Film Show on April 25, 1947, at Manson House, was exceptionally well attended, 38 members and visitors, mostly the latter, being present. Three films were shown:

(1) "OIL FROM THE EARTH", which illustrated, in detail, the drilling of an oil well. Three sequences were also included on prospecting, refining and distribution of petroleum.

(2) "AN ENGLISH OILFIELD". The search for oil in England portrayed pictorially, the ensuing story of the discovery and development of the Eakring oilfield resulting in an absorbing 20 minutes.

(3) "THE INSIDE STORY", the theory and practice of lubrication, demonstrating very forcefully a number of the principal factors encountered in the quest for perfect lubrication.

THE INSTITUTE OF PETROLEUM

A Special General Meeting of Corporate Members of the Institute of Petroleum will be held at Manson House, 26 Portland Place, London, W.1, on July 24, 1947, at 5.30 p.m. for the purpose of considering and, if thought fit, passing the necessary resolution or resolutions for alteration of the existing By-laws of the Institute.

A copy of the proposed new By-laws, as approved by the Council, is available with the Secretary of the Institute for inspection by any member during normal business hours, and will continue to be so available until the Special General Meeting is held for adopting the proposed new By-Laws.

THE GERMAN OIL INDUSTRY

Part II—*The Post-War Situation*

By L. W. HARFORD*

THIS phase really begins with the crossing of the Rhine by the British Second Army on March 23, 1945. From that moment on things happened apace. Within less than a month, a request had been received in London to assist the Army in getting the oilfields in the Hanover basin back into production. Allied troops were already in Hanover, and by May 2 they had reached the Baltic. On May 7 the entire German forces surrendered unconditionally.

C.I.O.S.

In the interval between March 23 and May 7 many parties of oilmen—British and American—had flown in, or in several cases marched in, behind the advancing armies and had descended on the "targets" selected for their urgent examination. There were two thoughts in mind: to capture for use against the Japanese any weapon that would aid and accelerate their defeat, and to secure for the subsequent benefit of the Allies, before vital records and plant could be destroyed or otherwise disposed of, knowledge of new processes devised or developed by German science during the war.

The body formed for this purpose was one of the many remarkable organizations which came into being during the war. Wholly integrated and allied—British and American—in leadership, inspiration, effort, personnel, and programme, C.I.O.S. as it became known—the short incisive abbreviation for the Combined Intelligence Objectives Sub-Committee—was the controlling body under which hundreds of "teams" of highly qualified British and American personnel pounced on their "targets" and went through them with fine tooth combs.

This is not the place to enlarge in any detail upon the findings of the teams appointed to examine the oil targets. The reports of the majority of the teams have been presented and published and there are many better qualified than the writer to enlarge on their work. Yet, as one who saw many of the teams at work, it seems only proper to pay a tribute to the excellence of their organization and the great keenness and enthusiasm with which they carried out their work, frequently arduous and by no means easy to accomplish. The greatest credit moreover is due to "T" Force, a wholly military organization whose role was firstly to seize the objective and then provide the administration, housing, feeding, transport, and general support of these teams of civilian experts, moreover seeing to the evacuation of their reports, documents, impedimenta, samples, photographs, and paraphernalia generally.

The general experience of all these teams was that the vast mechanism of the German war machine had come to a final and conclusive stop. The reason for this differed in the case of individual plants: the plant had been knocked out partially or completely; the workers had vanished; there was no further power to drive the plant; transport had ceased completely; essential supplies were exhausted; and always as the last straw the machinery of administration had broken down and there was no one left with any authority to give an order, and without an order nothing could be done. Did the Herr Major or the Herr Oberst require this to be done? Jawohl!

* Formerly Head of the Oil Branch, Control Commission for Germany (British Element).

it would be done. All that was necessary was the order.

But often, of course, no amount of orders could set the wheels going again, for the wheels no longer existed and there were no more to put in their place.

The Destruction

It was the awful stillness and the frightful destruction that made the most immediate impression upon everyone. Everywhere there was nothing but acres and acres of destruction — houses, factories, churches, buildings, plant, machinery.

A dramatic feature of every town was the towering of tall factory chimneys, unharmed and unshaken by the blizzard of destruction which had swept everything else to the ground. Occasionally a stack would be seen through which a shell had passed apparently without disturbing it in the slightest degree.

What was true of industry generally was certainly true of the synthetic oil plants and refineries, but with this difference, namely that the destruction of the synthetic oil plants was in general far more intense than was the destruction of the refineries.

The Oilfields

As for the fields, these were all but untouched and undamaged. Of "scorched earth" there was no trace at all, not even of the destruction of the most secret records and papers dealing with the Nazi's plans; all these were handed over to the C.I.O.S. teams on demand, mostly without demur though occasionally it was necessary to discourage attempts to withhold vital information.

True, oil production, like everything else had come to a stop but it was not long before the wells were in production once more.

Great credit is due to the handful of Military Government officers who set to work to get life in general going again. Starting absolutely from scratch they took complete command of the situation and within a matter of hours after their arrival at their posts the slow beginnings had been made of a gradual restoration, first, of the barest essential public and necessary services and, as the days drew on, of the basic foundations of the life of the people.

Upon "Mil Gov" in the Zone of Occupation allotted to the British fell a particular weight of responsibility in the matter of oil supplies, since what was left—with the synthetic oil plant out of action—was fundamentally the crude oil below the ground in a number of provinces in the British Zone. After a rapid examination into the progress in the gainful production of oil from shale in the Province of Wuerttemberg (capital—Stuttgart), it was concluded that if post-war Germany was going to have any supplies of petroleum (imports were then not contemplated), these supplies would have to come as to 95 per cent from the British Zone.

Accordingly, the order was given for full scale production of crude to be got under way, and credit is due to all who put their shoulders to the wheel to get this done. It was no easy task that faced the Germans to restore production, and without the constant and very real assistance of the Allies—Americans as well as British—results would not have been so quickly achieved. Details of actual 1945 production from the German oilfields (all of which are, as stated above, in the British Zone of Occupation) are as follows:

1945

Metric Tons

January	60,021	July	37,436
February	54,744	August	46,243
March	52,634	September	53,790
April	17,790	October	57,288
May	20,758	November	57,306
June	29,581	December	55,127
	235,528		307,190

Year 542,718 m. Tons.

The Refineries

The problem of the re-activation of German refining capacity to process the current production of crude and the stocks of topped crude and other residues discovered in storage here and there, particularly on the North German coast, was of quite a different order, and one of considerably greater complication. The Control Commission and Military Government were fortunate in having at their disposal a number of oilmen in the British and U.S. Forces who had made a very extensive survey of the German refineries, acting independently or in co-operation with the U.S.S.B.S., and were, therefore, in a position to advise the Commission in its consideration of the proposals put forward by the German refining industry.

Generally speaking, all refinery plant had been more or less extensively damaged by bombing, with the exception of the Vacuum Oil Company's valuable lubricating oil plant at Bremen, which was virtually untouched. It is an ironical example of the chances of war that while practically all the valuable refining capacity owned by British and American companies had been reduced to an unusable condition, it was the predominantly German-owned Deurag-Nerag plant at Misburg that was to be the mainstay of the immediate post-war refinery programme.

Anyone who had seen this plant, located a few miles outside Hanover, one of the most heavily bombed cities in Germany, as the armies drove over it, would have written it off as entirely beyond immediate repair. It is of interest that the U.S.S.B.S., in their Oil Division Final Report, give an analysis of the damage caused to this particular refinery, in the course of the nine air attacks which were launched over Misburg between June 20, 1944 and March 14–15, 1945.

As an example of the resilience, indefatigable patience, and high technical skill shown by the Germans over the length and breadth of the Reich in repairing the bomb damage to their plant and factories, the case of the Misburg Refinery is as good as any other to take. Nine times it was attacked and after each attack, even when serious and extensive damage had been caused, it was back on stream again within a few weeks. As an example of the effects of a typical attack the record of that of December 31, 1944, may be quoted:

Tons of bombs dropped, 233.
Tons of bombs dropped on target area, 29·5.
Daily production before attack, 470 tons.
Daily production after attack, none.
Back on stream, February 14, 1945.

Damage Done

Nerag.—Furfural unit, acid treating plant, blending and mixing plant, boiler and power house: heavily damaged.

Top vacuum unit, contact plant, new contact plant, old de-waxing and refrigeration plant, new de-waxing and refrigeration plant, propane de-asphalting plant, transfer pump houses: damaged.

Deurag.—Topping unit, Dubbs cracking unit, cooling tower system, transformer station, and power lines: heavily damaged.

Stabilization unit, gas polymerization, redistillation, transfer pumps, loading racks, piping, drum filling building, office building, laboratory, and workshop: damaged.

There were two further raids on February 13–14 and March 14–15, 1945, when the plant was again extensively damaged, the value of the damage caused in the final attack being put at Rm. 7,500,000 and calling for the comment—"This attack caused an indefinite shutdown."

The comment did not turn out to be correct, since by July 1, 1945, the plant

was working again at 53 per cent of its normal capacity.

Subsequently, the managing director of this plant was arrested by the British as one of those who had served the Nazis too well.

German Administrative Machinery

As the war drew to its close, the German administration machine, which had been gradually disintegrating under the devastating effect and range of Allied air attack, dissolved into thin air.

It was the determination of the Allies that Germany was to be rid of the Nazi system, hook, line, and sinker. We were, therefore, little interested or inclined to revive the administrative system which the Nazis had built up to control the oil industry.

However, portions of the mechanism which had been set up at industry level within the oil industry under the Nazi regime were considered to provide an extremely simple and flexible organization which could be of considerable service to Allied authority, after removal of any undesirable features.

The Commander-in-Chief in each Zone was entrusted with the responsibility for the administration of the entire German economy within his own Zone, and for the maintenance of the essential services, and law and order. He was furthermore authorized by inter-Allied directive to take all steps necessary to prevent disease and unrest amongst the civil population, which might endanger the occupation forces or the object of the occupation.

In the complete absence of any German central administration, it became a matter of supreme importance to establish local administration upon sound and democratic lines. In fact, the Potsdam directive called for the decentralization of the entire administration and in the actual circumstances there was nothing to be done but to set to and laboriously build up a new administration from the very bottom.

British Administration

The highest level of authority in each Zone was initially the province and in the British Zone there were four provinces, namely Schlesswig-Holstein, Hanover, Munster, and Dusseldorf, with Hansastadt Hamburg having the character, if not the status, of an independent province within a province.

Within the limits of policy laid down by 21st Army Group, each British Provincial Commander had complete authority for the administration within his own province and it was at this point that the demand for increased supplies of petroleum products began to make itself felt. The slogan had gone out that the Battle of the Winter was to be fought and won, and it was soon found that this battle was going to require very substantial supplies of petroleum.

The keynote of the Battle of the Winter was transport, but the formerly efficient German transport system by rail and canal had been battered almost to a standstill. The Royal Engineers performed prodigies of sustained effort in repairing blown bridges, building Bailey and other bridges over literally hundreds upon hundreds of canals and rivers. But still, as winter approached, the tonnage of traffic which the railways and canals could handle over and above military requirements was vastly below the level required to ensure minimum essential civilian needs.

Provincial Commanders pressed military transport into civilian service, but still it was not possible to satisfy the basic minimum of movement required to keep the country going and the call had to be made to the Home Government to supplement the slender supplies of oil, which the German oil industry could make available, for essential civilian needs.

By August 1945, the output of the German refineries had topped the 50,000 tons per month level and in November and December of that year

they were producing a net outturn in excess of 60,000 tons per month of finished products. But from the material available the outturn of light products was quite insufficient to meet the demands of the British, to say nothing of the French and American Zones.

It became, therefore, a necessity to import petrol and diesel oil required to distribute the vast quantities of foodstuffs the U.K. had to bring to Germany to keep the population alive, and other essential supplies and commodities.

To the North German Oil Control fell the responsibility (*a*) of ensuring maximum indigenous production, and (*b*) maximum economy in the consumption of *all* petroleum products, indigenous and imported, allocated to German needs. To this end, in conjunction with the Transport Authorities of the Control Commission and Military Government, the system which the Germans had utilized throughout the war for the rationing of petroleum products was partly resuscitated under Allied supervision.

Throughout the Zone, amongst all Control authorities, it was made clear that demand for road transport meant demands directly on the British taxpayer to provide the petrol and diesel oil. The British Control Authorities were continually reminded of this sober fact as the demand for supplies tended to increase. By means of drastic cuts it was possible to limit the demand upon the Home authorities to around 10,000 tons petrol and 15,000 tons diesel oil per month.

Distribution

At the outbreak of the war, the entire distribution machinery of the oil industry handling automotive fuels was formed into a pool, which was known as the Z.B.—the Zentral Buero—in which the constituent members participated to the extent of their pre-war share of the market. This organization the Allies in the Western Zone decided should continue in existence, subject to various technical changes in its constitution. It has functioned smoothly and efficiently and, apart from handling automotive fuel for civilian purposes, has been entrusted with the handling of a proportion of the supply of army petrol to the Occupation Forces in the British Zone.

The Future

The keynote to-day is German responsibility. In the early days the British in their Zone and, to a lesser extent, the Americans in their Zone (for the Americans shed responsibility much earlier) took over the functions of government within their Zones and for eighteen months ran the Zone, with the Germans as eager if rather bewildered collaborators.

Now the order has gone forth that the Germans must run their own show, for better or worse. No longer may the British issue orders. Having made their wishes clear, the Germans must carry on.

So far as the oil industry is concerned, there is certainly not the smallest doubt that it is well able and willing to carry on, but it is equally clear that the tasks facing the German authorities to-day are almost as formidable as those they faced at any time during the war.

W. J. Fraser & Co., Ltd., have been allocated a wartime factory by the Board of Trade. Located at Monk Bretton, near Barnsley, Yorks, plant is available for production to start during August. Eventually, the factory will be able to handle heavier equipment than is possible at Dagenham.

Latest bulletins of National Supply Export Corporation cover Power Slush Pumps, Type C-350 (No. 320), Power Slush Pump, Type C-250 (No. 321), and Type "W" Tubing Head (No. 327).

RECENT DEVELOPMENTS IN THE FISCHER-TROPSCH PROCESS

By S. R. CRAXFORD*

In the Fischer-Tropsch process, which was used in Germany on a large scale for the production of synthetic petrol, diesel oil and wax, carbon monoxide and hydrogen ("synthesis gas") are converted to liquid and solid hydrocarbons by allowing them to react at about 185° C in the presence of a cobalt catalyst. The synthesis gas was made, in Germany, from coke or brown coal but it may also be made from natural gas or other carbonaceous material. The synthesis reaction itself has a number of characteristics which make it difficult to carry out economically on the large scale.

Thus, a peculiarly difficult problem of heat transfer is involved, on account of the combination of two factors. The first is the removal of the very large heat of reaction, which amounts to some 20 per cent of the heat that would be liberated if the synthesis gas were burnt. The second is the extremely close control of temperature that is required; the temperature of the whole catalyst bed must be kept constant to within a few degrees if the reaction is to proceed successfully. The exact temperature depends on the conditions, but is always between 180 and 200°C.

The Germans used a fixed bed of catalyst, and as this had a low thermal conductivity they had to maintain their cooling medium—water at 10 to 13 atm pressure—at not more than 10°C below the temperature required in the catalyst. This in turn meant slow heat transfer per unit area of cooling surface, and as a result a very large area of cooling surface had to be provided, 200 to 400 sq.m/cu.m. catalyst, so that the reaction vessels were very complicated and expensive.

When synthesis gas is made from coal or coke it contains 5 to 6 per cent nitrogen, which becomes concentrated in the residual gas, and there is no practicable and economic method for removing this nitrogen and converting the methane in the residual gas back to carbon monoxide and hydrogen. Hence in Germany conditions had to be chosen for the synthesis under which as little as possible of the synthesis gas was converted to methane. Under such conditions the rate of the synthesis reaction is low, so that the output of products per unit volume of reaction space is also small.

All these difficulties have been avoided by modifications of the German process which are to be adopted by the Hydrocol Corporation for their projected plant in America, as described by Keith.* According to his account, synthesis gas is to be produced by partial combustion of natural gas with oxygen, and the synthesis itself carried out with a robust iron catalyst at about 300°C. The catalyst is not used in the normal way as a fixed bed of granules, but it is powdered and kept suspended in a stream of synthesis gas as a "fluidized bed." When gas is passed at a suitable rate through a bed of powder, for example of size range 20 to 40 microns, the particles become suspended in the gas stream and the bed expands until an equilibrium state is set up. None of the powder is carried off in the gas stream and the bed has the appearance of a gently boiling liquid. It exerts an hydrostatic pressure just as if it were a liquid and flows perfectly freely. On account of these properties it is referred to as being "fluidized" when in this state. If the gas rate is increased, the

* Fuel Research Station, Department of Scientific and Industrial Research.

expansion of the bed increases and finally, at very high gas rates, the powder is entrained in the gas stream and carried off. These high rates are not used in the present process.

The essential feature of a fluidized bed of catalyst is that it is very thoroughly stirred, so that its thermal conductivity is increased enormously. This means that the temperature of the cooling medium can be kept considerably below that of the catalyst bed, several hundred degrees if required, without undesirable temperature gradients developing in the bed. As a result, the rate of heat transfer per unit area of cooling surface is greatly increased, and the area of cooling surface necessary correspondingly decreased. The conventional reaction vessel with its elaborate cooling arrangements can therefore be replaced by a simple steel tower containing cooling coils through which water at 100°C is circulated. A reactor, employing a similar principle has been used successfully on a semi-technical scale in Germany for the Fischer-Tropsch synthesis, in which powdered catalyst was suspended in oil through which the synthesis gas was bubbled.

In a fluidized bed, every particle of catalyst is doing the same amount of synthesis, whereas in a fixed bed, catalyst at the exit end does very much less synthesis than catalyst at the entry end, on account of the falling partial pressures of the reactants through the bed. For this reason a fluidized bed is more efficient than a fixed bed, quite apart from its superiority from the heat transfer point of view.

Using the conventional reaction vessels, there was no incentive to improve the space-time yield, which was in fact kept low artificially, because the cooling arrangements could not cope with a higher rate of evolution of heat. In a fluidized bed of catalyst this limitation no longer exists, so that advantage can now be taken of an increased rate of reaction if means for producing such an increase were available.

When the process is operated at medium pressures, the catalyst is always covered with a film of wax and the reacting gases have to dissolve in this and diffuse through it to reach the catalyst surface, whereas at atmospheric pressure they come into contact with it directly. Hence, to get increased rates at medium pressures, conditions must be used under which very little, if any, wax is formed on the catalyst. Dr Michael, of I.G. Farben., showed that this could be done and the space-time yield increased by using certain iron catalysts at 300°C, although at this temperature a large amount of methane is formed in addition to the liquid hydrocarbons. A process based on these results could not therefore be developed on the conventional lines.

The American project, however, is able to use similar conditions, i.e., robust iron catalysts at about 300°C, because the fluidized catalyst bed allows advantage to be taken of the higher reaction rate. Moreover the American method of making synthesis gas is such that the methane formed in the synthesis is no longer a source of loss because it can be recirculated through the gas generators and reconverted into synthesis gas.

From the above discussion it is clear that the technique of the fluidized bed not only allows reaction vessels of a simple type to be used, but also reduces the number required. Its use, therefore, reduces the capital cost of the process. In the conventional process, however, the capital charges make up only about one third of the total cost of producing the primary product, so that the saving effected by the use of the fluidized bed technique must be considerably less than a third.

The cost of producing synthesis gas from coal or coke by the methods used in Germany, not including capital

charges, amounts to about 50 per cent of the total cost of producing primary products, so that the use of cheap synthesis gas, made from natural gas, would result in a big reduction in the total production cost. Thus the cheap synthesis gas appears to be a more important factor than the fluidized bed technique in accounting for the very low costs claimed for the American process.*

In assessing the advantages of the American over the German process it is clear, therefore, that two distinct factors are involved, namely, the use of the fluidized bed technique and of natural gas for the production of synthesis gas. The fluidized catalyst enables simple types of reaction vessel to be used, makes better use of the catalyst and allows conditions to be used—higher temperatures and robust iron catalysts—which give a higher output of products per unit of reaction space per hour. The production of synthesis gas from natural gas allows advantage to be taken of these conditions, but even apart from this, its low cost is the most important item contributing to the reduction of the American cost estimates below the German figures.

GERMAN OIL PRODUCTION

DETAILS issued by the North German Oil Control (Control Commission for Germany) show that crude oil production for the British Zone during 1946 totalled 642,682 m. tons, an increase of 99,964 m. tons, or 18.4 per cent, over the 1945 figure of 542,718 m. tons. The German oil industry comprises a large number of small producing fields situated mainly in the Hannover region, Schleswig-Holstein, and the Ems Land, sometimes as many as four companies operating one field. Productions of individual fields in 1945 and 1946 are given as:

FIELD	1945	1946
	Metric Tons	
Broistedt	1,614	2,547
Calberlah	152	557
Eddesse-Oelheim	2,960	3,011
Ebra	44	571
Eicklingen	13,555	14,301
Emlichheim	5,141	24,122
Etzel	1,821	4,719
Fuhrberg	33,867	51,078
Georgsdorf	9,269	14,897
Gifhorn	1,702	2,129
Hademstorf	4,108	6,704
Haenigsen	35,146	37,553
Heide	90,569	74,364
Hohenassel	31,534	48,642
Lingen	16,255	40,709
Meckelfeld	2,325	2,661
Moelme	7,766	7,158
Nienhagen	131,547	129,909
Oberg	8,174	9,494
Reitbrook	34,471	34,272
Steimbke	23,572	46,007
Thoeren	16,039	19,212
Wesendorf	51,418	45,706
Wietze	19,869	22,359
Total	542,718	642,682

GAS PRODUCTION	1945	1946
	1,000 *cu. m.*	
Bentheim	71,033	106,372
Lesser Fields	655	2,932
Total	71,688	109,304

DRILLING

During 1946 exploration drilling totalled 23,180 metres, 21 wells being completed with 1 productive. Exploitation drilling amounted to 56,496 metres, with 48 wells productive out of 89 drilled.

Corresponding figures for 1945 were 16,426 metres of exploration and 60,695 metres of exploitation drilling. No wells were completed in that year.

* Keith, P. C. *Oil Gas J.*, 15.6.46, **45** (6), 102.

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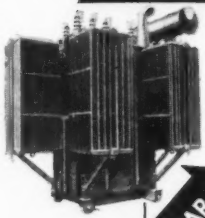

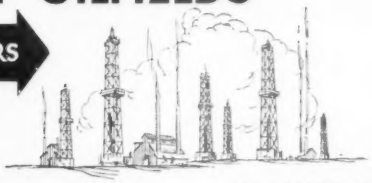

and REFINERIES..

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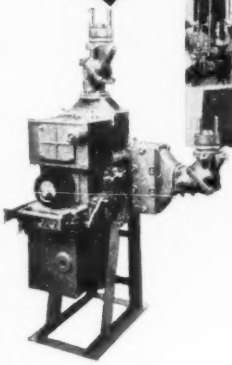

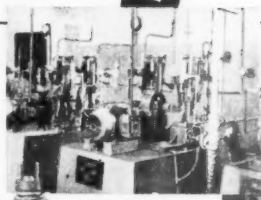

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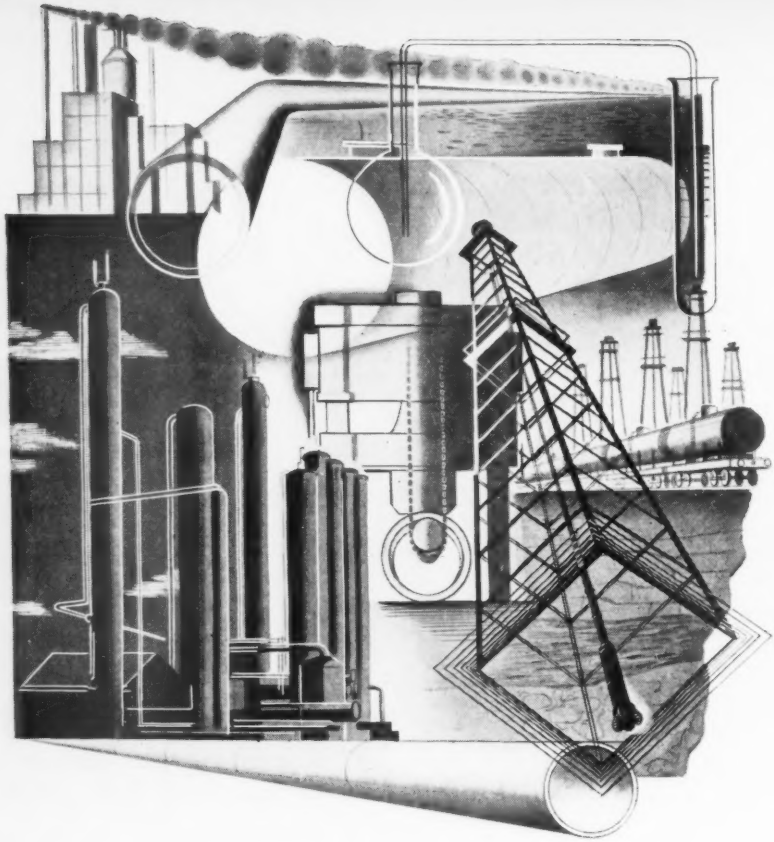

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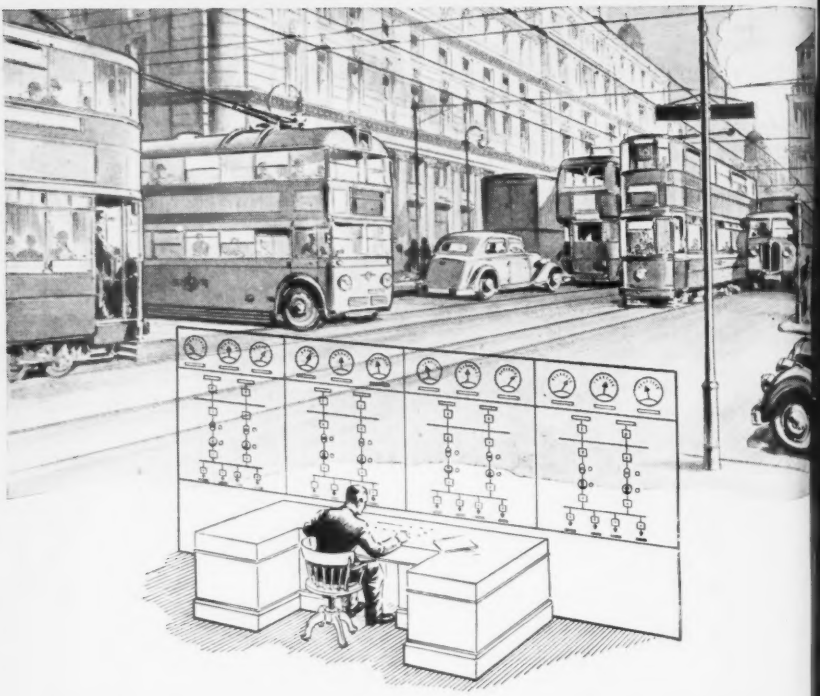

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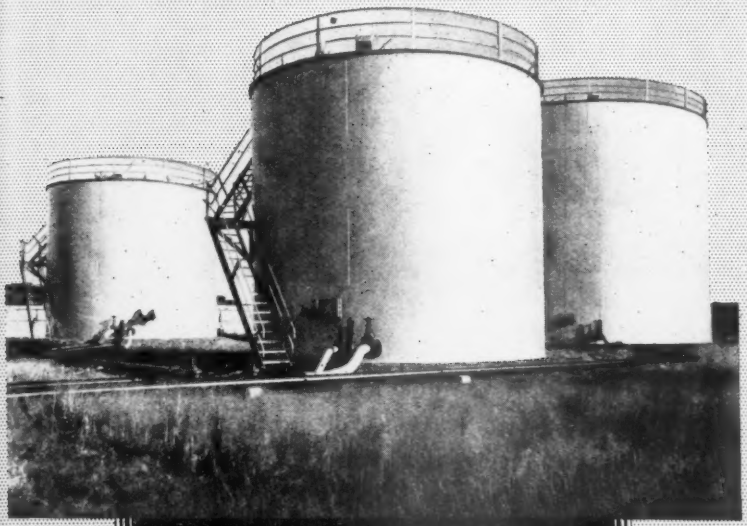

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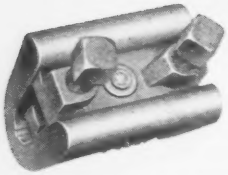

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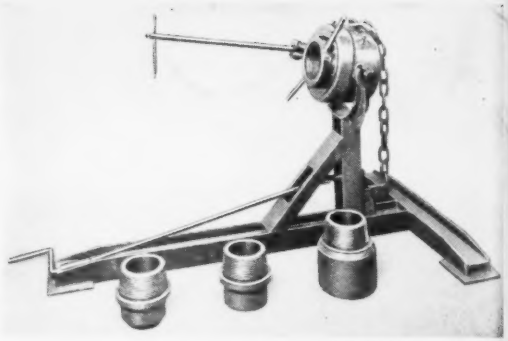

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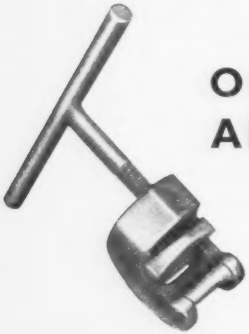

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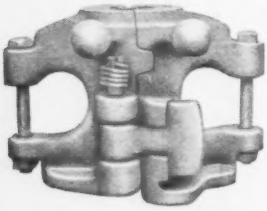

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